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**TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371**

Attorney Docket No. 02051

U.S. Application No. (if known)
see 37 CFR 1.107 088533

INTERNATIONAL APPLICATION NO.
PCT/EP00/10842

INTERNATIONAL FILING DATE
November 3, 2000

PRIORITY DATE CLAIMED
November 3, 1999

TITLE OF INVENTION
AUTOMATIC CONTRAST FOCUSING WITH THREE OPTICAL PATHS

APPLICANT(S) FOR DO/EO/US

Ralf Christoph & Christian Lotze

Applicant herewith submits to the United States Designated Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☒ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
 - a. ☐ are transmitted herewith (only if not required by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 16 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ As assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☐ Other items or information:



23338

PATENT TRADEMARK OFFICE

10/088533

JC13 Rec'd PCT/PTO 10 3 APR 2002

17. <input checked="" type="checkbox"/> The following fees are submitted:				CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492 (a)(1)-(5):					
Neither international preliminary examination fee (37 CFR 1.482)					
Nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO					
And International Search Report not prepared by EPO or JPO..... \$1,040.00					
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by EPO or JPO.....\$890.00					
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International search fee (37 CFR 1.445(a)(2)) paid to USPTO..... \$740.00					
International preliminary examination fee paid to USPTO (37 CFR 1.482) But all claims did not satisfy provisions of PCT Article 33(1)-(4).....\$710.00					
International preliminary examination fee paid to USPTO (37 CFR 1.482) And all claims satisfied provisions of PCT Article 33(1)-(4)..... \$100.00					
ENTER APPROPRIATE BASIC FEE AMOUNT =				\$890.00	
Surcharge of \$130.00 for furnishing oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	28 -20=	8	X \$18.00	\$144.00	
Independent Claims	2 -3=		X \$84.00	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				\$	
TOTAL OF ABOVE CALCULATIONS =				\$1034.00	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).				\$517.00	
SUBTOTAL =				\$517.00	
Processing fee of \$130.00 for furnishing English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
TOTAL NATIONAL FEE =				\$517.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31).				\$40.00	
TOTAL FEES ENCLOSED =				\$557.00	
				Amount to be refunded:	\$
				charged:	\$

- a. ☒ A check in the amount of \$557.00 to cover the above fees is enclosed.
- b. ☐ Please charge my Deposit Account No. 04-0753 in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.
- c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 04-0753. A duplicate copy of this sheet is enclosed.
- d. ☐ A payment of \$ _____ is made by credit card. A Credit Card Payment Form (PTO-2038) is attached hereto. The Commissioner is hereby authorized to charge payment of any additional filing fees required under 37 CFR 1.16 or any patent application processing fees under 37 CFR 1.17, or credit any over payment to the credit card account shown on the attached Credit Card Payment Form. Refund of all amounts overpaid, including those of twenty-five dollars or less, is specifically requested. Any fees not accepted by the credit card shown on Form PTO-2038 may be charged to Deposit Account No. 04-0753.

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28666

REGISTRATION NUMBER

107088533

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Dkt. 02051

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

Group Art Unit:

RALF CHRISTOPH et al

Examiner:

Serial No.: US National Phase of
PCT/EP00/10842

Filed: concurrently herewith

For: AUTOMATIC CONTRAST FOCUSING WITH THREE OPTICAL PATHS

PRELIMINARY AMENDMENT

Honorable Assistant Commissioner for Patents
Washington, DC 20231

Sir:

Before calculation of the filing fee, please amend the
above-identified application as follows:

IN THE ABSTRACT:

Please add the following abstract:

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ARLINGTON, VIRGINIA 22202-3417

703 412-1155

(The following information was obtained from the FBI files maintained at the New York City Office.)

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IN THE CLAIMS:

Please amend the claims as set forth hereinbelow and in the attached appendix:

3. (Amended) Method according to claim 1, characterized in that the beam proceeding from the point is split into optical paths of different lengths through optical elements that are distributed in front of a sensor.

4. Method according to claim 1, characterized in that flat face-plates of different thicknesses, which are arranged in a matrix shape, can be used as the optical element.

5. (Amended) Method according to claim 1, characterized in that the sensor or its working field is divided into several measuring areas for simultaneous distance measuring of various areas of the object.

6. (Amended) Method according to claim 1, characterized in that the respective contrast distribution is adapted to a parabola, whose vertex corresponds to a contrast value, at which the point to be measured is sharply depicted on the working plane of the corresponding sensor.

7. (Amended) Method according to claim 1, characterized in that the contrast distributions, which are allocated to the optical paths with different lengths, run in an overlapping manner in such a way that in the measuring area contrast values are determined from a minimum number of contrast

distributions for a distance that is to be measured, with this number being sufficient for calculating the contrast distribution for the sensor or optical path for a sharp depiction of the point to be measured via the selected optical path to the sensor.

8. (Amended) Method according to claim 1, characterized in that an image sensor or a multiple-chip camera is used as the sensor.

9. (Amended) Method according to claim 1, characterized in that the sensor is coupled with a position control loop of a CNC control system for the point-by-point scanning measurement of a surface of the object.

10. (Amended) Method according to claim 1, characterized in that for the purpose of achieving optical paths with different lengths, the beam proceeding from the point penetrates a piezo-electric plate, which is arranged in front of a sensor.

11. (Amended) Method according to claim 1, characterized in that the beam proceeding from the point penetrates flat face-plates of different thicknesses that are arranged on a rotating disk.

12. (Amended) Method according to claim 1, characterized in that the beam proceeding from the point is directed via a tilting mirror to at least three sensors.

27. (Amended) Device according to claim 16, characterized in that the optical sensor (14, 20, 22) is arranged on a fastening device that comprises a piezo-element to be able to change the distance to the point (10).

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[Handwritten notes in cursive script, mostly illegible due to blurriness.]

Respectfully submitted,

Ira J. Schultz
Registration No. 28666

APPENDIX

IN THE CLAIMS:

3. (Amended) Method according to claim 1 [or 2], characterized in that the beam proceeding from the point is split into optical paths of different lengths through optical elements that are distributed in front of a sensor.

4. Method according to [at least one of the previous claims] claim 1, characterized in that flat face-plates of different thicknesses, which are arranged in a matrix shape, can be used as the optical element.

5. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that the sensor or its working field is divided into several measuring areas for simultaneous distance measuring of various areas of the object.

6. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that the respective contrast distribution is adapted to a parabola, whose vertex corresponds to a contrast value, at which the point to be measured is sharply depicted on the working plane of the corresponding sensor.

7. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that the contrast distributions, which are allocated to the optical paths with

different lengths, run in an overlapping manner in such a way that in the measuring area contrast values are determined from a minimum number of contrast distributions for a distance that is to be measured, with this number being sufficient for calculating the contrast distribution for the sensor or optical path for a sharp depiction of the point to be measured via the selected optical path to the sensor.

8. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that an image sensor or a multiple-chip camera is used as the sensor.

9. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that the sensor is coupled with a position control loop of a CNC control system for the point-by-point scanning measurement of a surface of the object.

10. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that for the purpose of achieving optical paths with different lengths, the beam proceeding from the point penetrates a piezo-electric plate, which is arranged in front of a sensor.

11. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that the beam proceeding from the point penetrates flat face-plates of different thicknesses that are arranged on a rotating disk.

12. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that the beam proceeding from the point is directed via a tilting mirror to at least three sensors.

13. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that the beam proceeding from the point penetrates a lens package of a zoom lens of the optical sensor.

14. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that the optical sensor is arranged on a fastening device that comprises a piezo-element to be able to change the distance to the point.

15. (Amended) Method according to [at least one of the previous claims] claim 1, characterized in that the beam proceeding from the point penetrates a CCD layer with pixel areas deviating from one another.

18. (Amended) Device according to claim 16 [or 17], characterized in that in front of the one sensor (14, 20, 22), optical elements are arranged for splitting the beam proceeding from the point (10) into optical paths of different lengths.

19. (Amended) Device according to [one of the previous claims] claim 16, characterized in that flat face-plates of different thicknesses, arranged matrix-like, are used as the

optical element.

20. (Amended) Device according to [one of the previous claims] claim 16, characterized in that the sensor (14, 20, 22) or its working field is divided into several measuring areas for simultaneous distance measuring of various areas of the object (12).

21. (Amended) Device according to [one of the previous claims] claim 16, characterized in that the sensor (14, 20, 22) is an image sensor or a multiple-chip camera.

22. (Amended) Device according to [one of the previous claims] claim 16, characterized in that the sensor (14, 20, 22) is coupled with a position control loop of a CNC control system for the point-by-point scanning measurement of a surface of the object (12).

23. (Amended) Device according to [one of the previous claims] claim 16, characterized in that for the purpose of achieving optical paths with different lengths, the beam proceeding from the point penetrates a piezo-electric plate arranged in front of a sensor (14, 20, 22).

24. (Amended) Device according to [one of the previous claims] claim 16, characterized in that in front of the sensor (14, 20, 22) a rotating disk, which is penetrated by the beam, is arranged, on which flat face-plates of different thicknesses are located.

28. (Amended) Device according to [one of the previous claims] claim 16, characterized in that the beam proceeding from the point (10) penetrates a CCD layer with pixel areas deviating from one another.

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Automatic Contrast Focusing with Three Optical Paths

5 The invention relates to a method for determining the distance from a point of an object to a specified reference point such as a sensor by measuring contrast values of the point that is represented in the working plane of the sensor, in particular for a scanning profile determination of a material surface with a coordinate measuring instrument, wherein an optical system, which comprises the sensor and is arranged in a probe that is displaceable relative to the object surface, is adjusted in relation to the object, and wherein from the position of the optical system in relation to the object, the distance and/or its profile is determined, wherein in the imaging beam path of the optical system the contrast values of the depicted point are measured at the ends of at least two optical paths of different lengths. Furthermore the invention relates to a device for determining the distance from a point of an object to a specified reference point such as a sensor by measuring contrast values of the point that is represented in the working plane of the sensor, in particular for the scanning profile determination of a material surface with a coordinate measuring instrument, wherein an optical system, which comprises the sensor and is arranged in a probe that is displaceable relative to the object surface, is adjusted in relation to the object and wherein from the position of the optical system in relation to the object the distance and/or its profile can be determined, wherein in the imaging beam path of the optical system the contrast values of the depicted point can be measured at the ends of at least two optical paths of different lengths.

For the purpose of surface analysis of material surfaces, optically scanning measuring systems are used, which operate based on the automatic focusing principle. For example individual automatic focal points are measured based on the contrast method during the scanning process. In order to record complete contours, this method requires long measuring periods. Several seconds are required for each measuring point.

From P. Profos, T. Pfeifer (editors): Handbuch der industriellen Messtechnik [Handbook of industrial metrology], 5th edition, Oldenbourg Publishing Company, Munich-Vienna 1992, p. 455; 456 a method of the kind described at the beginning is known. There, laser distance sensors are used for detecting surface topographies. In the familiar method, light of a laser diode is cast onto the material surface with a collimator and a movable object. The light that is reflected from the surface reaches an optoelectronic focus detector in the form of a modem line via the objective lens, the collimator and a beam splitter. The objective lens follows in dependence upon the surface topography. From its movement, the height profile is determined. One disadvantage of this method consists of the high sensitivity towards property changes of the material surface.

From H. Naumann. G. Schröder: Bauelemente der Optik, Taschenbuch der technischen Optik (Elements of Optical Systems, Pocket Book on Technical Optics), 6th edition, C. Hanser Publishing Company, Munich-Vienna 1992, p. 348, 349, automatic focusing through contrast measurement is known, wherein three optical paths of different lengths are used

for photometric contrast measurement and a focus position is recognized based on differences in contrast.

From DE-Z: VDI-Z 131 (1989) No. 11, p. 12-16 R.-J.

Ahlers, W. Rauh: "Koordinatenmesstechnik mit
Bildverarbeitung" (Coordinate metrology with image
processing) a coordinate measuring system based on the
automatic focusing principle is known, where three-
dimensional object measurement can occur through contrast
analysis with spatial frequency measurement of data supplied
by an image-detecting sensor.

WO 99/53271 describes a method for determining the
profile of a material surface by point-by-point scanning
with a coordinate measuring device according to the auto-
focusing principle, wherein an optical system that is
arranged in a probe that can move in relation to the
material surface automatically adjusts its distance to the
material surface, and wherein from the position of the
optical system in relation to the material surface, the
profile of the material surface is determined by measuring
the photometric contrast in the path of the image rays of
the optical system at the ends of two optical paths of
different lengths and by adjusting the distance of the
optical system such that the measured contrast values are
equal or nearly equal. When the probe is moved towards the
material surface or away from it, the position of the plane
depicted by the optical system changes in relation to the
ends of the two optical paths on which the contrast is
measured. The amount of each contrast value depends on the
distance between the imaging plane of the surface of the
material and the ends on which the contrast is measured.

Equal contrast values occur when the imaging plane has the same distance to the ends of the optical paths. Modifying the probe position in relation to the surface until the measured contrast values are equal leads to exact focusing.

5 Underlying the present invention is the objective of further designing a method and a device of the above-described kind in such a way that the distance between the object and the reference point such as the optical system or sensor can be determined extremely quickly and accurately,
10 wherein if necessary several points in the plane of the object should be measured simultaneously. At the same time the device should be simplified, and thus the proneness to trouble should be reduced.

15 With regard to the method, the problem is basically resolved through the fact that in the imaging beam path of the optical system at the end of three optical paths of different lengths contrast distributions of the beams are determined according to the distance to the point of the object that is to be measured through at least one sensor
20 and that a relationship is established between the resulting contrast distributions as well as that for determining the distance between the point to be measured and the reference point contrast values of the point, which is depicted via the at least three optical paths with different lengths, are
25 measured at a specified distance and transformed to previously determined contrast distributions at the end of one of the optical paths.

In particular the invention here provides that a sensor at all times is allocated to each of the optical paths with different lengths. Alternatively, there is the possibility

of splitting the beam proceeding from the point into the optical paths with different lengths through optical elements that are arranged in front of a sensor. The optical elements can be flat face-plates, which are arranged in a matrix shape, with different thicknesses, through which the beam is split into partial beams of different path lengths.

Furthermore there is the possibility of dividing the sensor into several measuring areas for the purpose of simultaneous distance measurement in different areas of the object.

In particular, it is provided that the respective contrast distribution is adapted to a parabola, wherein its vertex corresponds to the contrast value at which a point is sharply depicted on the working plane of the sensor. By determining the parabola and its vertex, the optical system can then be adjusted to the point so that the point is depicted in a well-defined manner in the working plane. The contrast distributions can additionally be standardized.

In a further development of the invention, the contrast distributions that are assigned to the optical paths with different lengths overlap such that in the measuring area with a distance that is to be measured, contrast values of a minimum number of contrast distributions are determined, which is sufficient for calculating the contrast distribution for the sensor or the optical path for a sharp depiction of the point that is to be measured through the selected optical path onto the sensor. If there is a possibility of depicting optical paths with different lengths on a sensor, then three or more sensors suitable for

measuring contrast values can be arranged such that their working planes run in different positions to the measuring axis.

Image sensors or CCD or multiple-chip cameras can be used as sensors.

The sensor(s) used for measuring the contrast values can be integrated in particular in a coordinate measuring device in order to measure the distance in the Z-direction. It is also possible to couple the sensor with a position control loop of a CNC control system in order to realize a scanning of a surface that is to be measured.

According to the invention, the knowledge that the contrast values measured at different distances between the measuring point and the working plane of a sensor are located roughly on a parabola is utilized, wherein the contrast values at the vertex correspond to the optical distance between the working plane of the sensor and the point at its sharp depiction. When using several sensors, which have different distances to a point that is to be represented, and determining the contrast value curves and standardizing them based on the geometric relation of the sensors or optical paths to each other, then through determination of the contrast values measured in each sensor at a specified distance, the contrast value curve of the sensor, on whose working plane the point is to be depicted sharply, can be calculated due to the previously known relation of the contrast value curves or parabolae to each other. The point to be measured is then in the focusing plane of the optical system allocated to the sensor. After calculating the appropriate contrast value curve, only the

vertex still has to be determined to be able to obtain the distance that are to be maintained and if need be set between the sensor and the measuring point.

5 If for reasons of measuring accuracy or the simultaneous determination of geometries in a plane (XY-plane) that does not contain the distance axis Z it is required that the measuring point be sharply depicted on the working plane of the selected sensor as reference point,
10 then in the event that only distance is determined, it is basically not necessary to change the distance between the optical system that contains the sensor or sensors and the object insofar as the determined contrast values are in measuring areas that enable a calculation of a contrast
15 value curve and thus the distance between the sensor allocated to it and the object. Accordingly, only an adjustment in the XY-plane occurs.

Even if beneficially each optical beam path is allocated a separate sensor, a single sensor can also be
20 allocated to all beam paths, wherein the optical paths with different lengths are realized by arranging matrix-like in front of it suitable optical elements such as flat face-plates of different thicknesses.

Optical system and sensor or sensors of course are
25 always adjusted as a unit. If the optical system is designed as a zoom lens, the necessary conversion factors must be taken into consideration as a function of the positions of the lenses that are incorporated in the optical system.

With regard to the device, the problem on which the invention is based is essentially resolved through the fact that, in the imaging beam path of the optical system at the

end of at least three optical paths of different lengths, at least one sensor is arranged for determining the contrast distributions of the beams according to the distance to the point of the object that is to be measured. Preferably one sensor each is assigned to each of the optical paths with different lengths. The one sensor can also be allocated optical elements for splitting the beams proceeding from the point into optical paths of different lengths. The optical element can be flat face-plates of different thicknesses, which are arranged in a matrix shape.

A further development provides for the fact that the sensor and/or its working field is divided into several measuring areas for simultaneous distance measuring of different areas of the object. The sensor can be an image sensor or a multiple-chip camera.

Furthermore it is provided that the sensor is coupled with a position control loop of a CNC control system in order to realize point-by-point scanning measurement of a surface of the object.

In order to obtain a beam proceeding from the point in optical paths with different lengths, the sensor can be arranged in front of a piezo-electric flat face-plate, through which the beam penetrates. It is also possible to arrange a rotating disk penetrated by the beam in front of the sensor on which face plates of different thicknesses are arranged.

Furthermore the device can contain a tilting mirror so that the beam path proceeding from the point is directed to at least three sensors. Furthermore the sensor can contain

a lens package of a zoom lens, which is penetrable by the beam

In order to change the distance of the optical sensor to the point, it can furthermore be arranged on a fastening device that comprises a piezo-element.

Finally, another refinement provides that the beam proceeding from the point penetrates a CCD layer with pixel areas diverging from one another.

Further details, benefits and features of the invention result not only from the claims, the features contained in them - either by themselves and/or in combination - but also from the following description of a preferred embodiment, which is shown in the drawing.

Depicted is:

- Fig. 1 a basic representation of a sensor arrangement for determining the distance of a point and
- Fig. 2 principal courses of contrast value curves determined with the sensors from Fig. 1.

In order to determine the distance of a point 10 of an object 12 or its surface to a reference point, such as a sensor 14 in the embodiment, which can be an element of a probe of a coordinate measuring device, which is not explained and shown in detail, according to the invention, one uses the knowledge that distance-dependent contrast values, i.e. the entire contrast value course, is located roughly on a parabola. Changing the distance of the sensor 14 to the point 10 to be measured results (as a function of the imaging plane to the working plane) in a contrast value course in the sensor 14 that corresponds to a parabola and

is labeled with the reference number 16 in Fig. 2. For this purpose, a beam path is directed via a lens 18 to the working plane of the sensor 14 in the conventional manner. According to the invention, the sensor 14 is assigned two additional sensors 20, 22, which have different optical distances to the point 10 to be measured. This is accomplished by dividing the beam 20 that is guided to the sensor 14 via beam splitters 22, 24 and deflection elements such as prisms 26, 28 in order to reach the sensors 20, 22, which in turn can run in relation to their working planes also at difference distances to the point 10 that is to be measured. The lens 18 with the deflection devices 22, 24, 26, 28 as well as the sensors 14, 20, 22 form a unit and can, as mentioned above, be a probe of a coordinate measuring device.

In order to be able to determine in the embodiment the distance between the sensor 14, i.e. its working plane, to a point that is to be measured, in the embodiment point 10, from the contrast values, which are determined via the sensors 14, 20, 22 at a specified distance, without requiring that the point 10 be sharply depicted in one of the working planes of the sensors 14, 20, 22, initially the respective contrast value course that is to be measured in the sensors 14, 20, 22 is determined so that measuring curves are obtained, which are shown in Fig. 2, i.e. the parabola 16 of sensor 14 as well as the parabolae 30, 32, which run offset due to the sensors 20, 22 being arranged at different optical distances compared to the sensor 14, wherein the parabola 30 is allocated to sensor 22 and the parabola 32 to sensor 20. This offsetting of the parabolae

16, 30, 32 with regard to their distance results from the circumstance that the sensors 14, 20, 22 have different sharpness planes, which are labeled in Fig. 1 with the reference numbers 34, 36 and 38.

5 If consequently the probe, which comprises the sensors 14, 20, 22 as well as the optical system, is adjusted in relation to the point 10 in such a way that this point is located in the sharpness plane 36 of the sensor 20, then a contrast value 40 is obtained, which corresponds to the
10 vertex of the parabola 32. The same applies in relation to the adjustment of the probe to the sharpness planes 34 and 38 of the sensors 14 and 22.

After the contrast curves 16, 30, 32 have been determined and placed into relation with each other, it is
15 now only required to determine the respective contrast values of the sensors 14, 20, 22 at a desired distance of the probe to a point that is to be measured; from these contrast values then the vertex of the sensor, in the embodiment sensor 14, which corresponds to distance Z, and
20 where the point to be measured is sharply depicted on the working plane of the sensor 14, can be calculated immediately. This is explained in Fig. 2. If the contrast values of the measuring point 10 depicted in the sensors 14, 20, 22 are determined at a distance Z1, then measuring
25 values P1, P2 and P3 are obtained, wherein P3 is the measuring value of sensor 14. The measuring value P1 corresponds to the contrast value, which was determined from sensor 22, and measuring value P3 corresponds to the contrast value, which was determined from sensor 20. Since the relationship between the contrast value curves 16, 30,

32 to each other is known, it is now only necessary to allocate to the measuring values P1 and P3 measuring values on the contrast value curve 16 of the sensor 14 so that overall three measuring values P1', P2' and P3' are obtained, which are located on the stored measuring value curve of the sensor 14. All these values allow then the entire measuring value course and thus their vertex P4 to be determined, to which a distance Z is allocated, at which the measuring point 10 is sharply depicted on the working plane of the sensor 14. Thus, the distance Z between the measuring point and the probe can be determined without requiring the probe itself to be adjusted compared to the object in order to measure several contrast values for each sensor 14, 20, 22.

Patent Claims

1. Method for determining the distance between a point of an object to a specified reference point, such as a sensor, by measuring contrast values of the point that is represented in the working plane of the sensor, in particular for a scanning profile determination of a material surface with a coordinate measuring instrument, wherein an optical system, which comprises the sensor and is arranged in a probe that is displaceable relative to the object surface, is adjusted in relation to the object and wherein from the position of the optical system in relation to the object the distance and/or its profile is determined, wherein in the imaging beam path of the optical system the contrast values of the depicted point are measured at the ends of at least two optical paths of different lengths,

characterized in that in the imaging beam path of the optical system at the end of at least three optical paths of different lengths contrast distributions of the beams are determined according to the distance to the point of the object that is to be measured through at least one sensor and that a relationship is established between the resulting contrast distributions as well as that for determining the distance between the point to be measured and the reference point contrast values of the point, which is depicted via the at least three optical paths with different lengths, are measured at a specified distance and transformed to previously determined contrast distributions at the end of one of the optical paths.

2. Method according to claim 1, characterized in that

one sensor each is assigned to each of the optical paths of different lengths.

3. Method according to claim 1 or 2, characterized in that the beam proceeding from the point is split into optical paths of different lengths through optical elements that are distributed in front of a sensor.

4. Method according to at least one of the previous claims, characterized in that flat face-plates of different thicknesses, which are arranged in a matrix shape, can be used as the optical element.

5. Method according to at least one of the previous claims, characterized in that the sensor or its working field is divided into several measuring areas for simultaneous distance measuring of various areas of the object.

6. Method according to at least one of the previous claims, characterized in that the respective contrast distribution is adapted to a parabola, whose vertex corresponds to a contrast value, at which the point to be measured is sharply depicted on the working plane of the corresponding sensor.

7. Method according to at least one of the previous claims, characterized in that the contrast distributions, which are allocated to the optical paths with different lengths, run in an overlapping manner in such a way that in the measuring area contrast values are determined from a minimum number of contrast distributions for a distance that is to be measured, with this number being sufficient for calculating the contrast distribution for the sensor or

optical path for a sharp depiction of the point to be measured via the selected optical path to the sensor.

8. Method according to at least one of the previous claims, characterized in that an image sensor or a multiple-chip camera is used as the sensor.

9. Method according to at least one of the previous claims, characterized in that the sensor is coupled with a position control loop of a CNC control system for the point-by-point scanning measurement of a surface of the object.

10. Method according to at least one of the previous claims, characterized in that for the purpose of achieving optical paths with different lengths, the beam proceeding from the point penetrates a piezo-electric plate, which is arranged in front of a sensor.

11. Method according to at least one of the previous claims, characterized in that the beam proceeding from the point penetrates flat face-plates of different thicknesses that are arranged on a rotating disk.

12. Method according to at least one of the previous claims, characterized in that the beam proceeding from the point is directed via a tilting mirror to at least three sensors.

13. Method according to at least one of the previous claims, characterized in that the beam proceeding from the point penetrates a lens package of a zoom lens of the optical sensor.

14. Method according to at least one of the previous claims, characterized in that the optical sensor is arranged on a fastening device that comprises a piezo-element to be able to change the distance to the point.

15. Method according to at least one of the previous claims, characterized in that the beam proceeding from the point penetrates a CCD layer with pixel areas deviating from one another.

5 16. Device for determining the distance of a point (10) of an object (12) to a specified reference point such as a sensor (14, 20, 22) by measuring contrast values of the point depicted in the working plane of the sensor, in particular for a scanning profile determination of a
10 material surface with a coordinate measuring instrument, wherein an optical system, which comprises the sensor and is arranged in a probe that is displaceable relative to the object surface, is adjusted in relation to the object, and wherein from the position of the optical system in relation
15 to the object the distance and/or its profile is determined, wherein in the imaging beam path of the optical system the contrast values of the depicted point are measured at the ends of at least two optical paths of different lengths, characterized in that in the imaging beam path of the
20 optical system at the end of at least three optical paths of different lengths, at least one sensor (14, 20, 22) is arranged for the purpose of determining the contrast distributions of the beam in dependence upon the distance to the point (10) of the object (12).

25 17. Device according to claim 16, characterized in that in each case one sensor (14, 20, 22) is assigned to each of the optical paths with different lengths.

 18. Device according to claim 16 or 17, characterized in that in front of the one sensor (14, 20, 22), optical

elements are arranged for splitting the beam proceeding from the point (10) into optical paths of different lengths.

19. Device according to one of the previous claims, characterized in that flat face-plates of different thicknesses, arranged matrix-like, are used as the optical element.

20. Device according to one of the previous claims, characterized in that the sensor (14, 20, 22) or its working field is divided into several measuring areas for simultaneous distance measuring of various areas of the object (12).

21. Device according to one of the previous claims, characterized in that the sensor (14, 20, 22) is an image sensor or a multiple-chip camera.

22. Device according to one of the previous claims, characterized in that the sensor (14, 20, 22) is coupled with a position control loop of a CNC control system for the point-by-point scanning measurement of a surface of the object (12).

23. Device according to one of the previous claims, characterized in that for the purpose of achieving optical paths with different lengths, the beam proceeding from the point penetrates a piezo-electric plate arranged in front of a sensor (14, 20, 22).

24. Device according to one of the previous claims, characterized in that in front of the sensor (14, 20, 22) a rotating disk, which is penetrated by the beam, is arranged, on which flat face-plates of different thicknesses are located.

25. Device according to one of the previous claims,

characterized in that the device contains a tilting mirror,
from which the beam proceeding from the point (10) can be
directed to at least three sensors (14, 20, 22).

26. Device according to one of the previous claims,
5 characterized in that the sensor (14, 20, 22) is equipped
with a lens package of a zoom lens, which can be penetrated
by the beam.

27. Device according to one of the previous claims,
10 characterized in that the optical sensor (14, 20, 22) is
arranged on a fastening device that comprises a piezo-
element to be able to change the distance to the point (10).

28. Device according to one of the previous claims,
15 characterized in that the beam proceeding from the point
(10) penetrates a CCD layer with pixel areas deviating from
one another.

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES
PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

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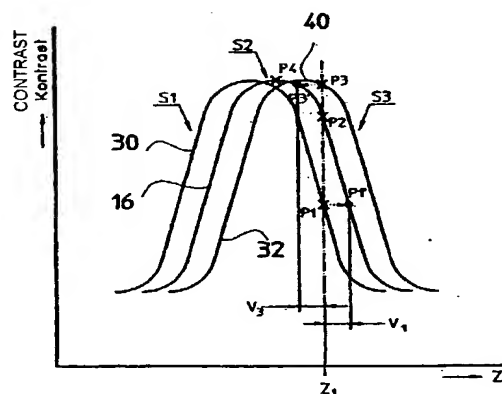
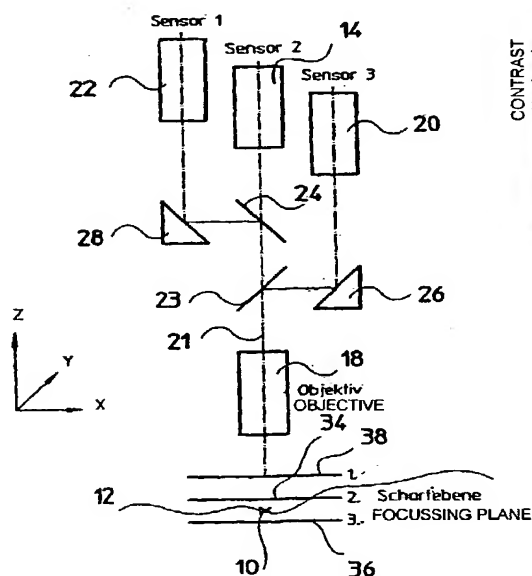
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[Fortsetzung auf der nächsten Seite]

(54) Title: **AUTOMATIC CONTRAST FOCUSSED WITH THREE OPTICAL PATHS**

(54) Bezeichnung: **KONTRASTAUTOFOKUS MIT DREI OPTISCHEN WEGEN**

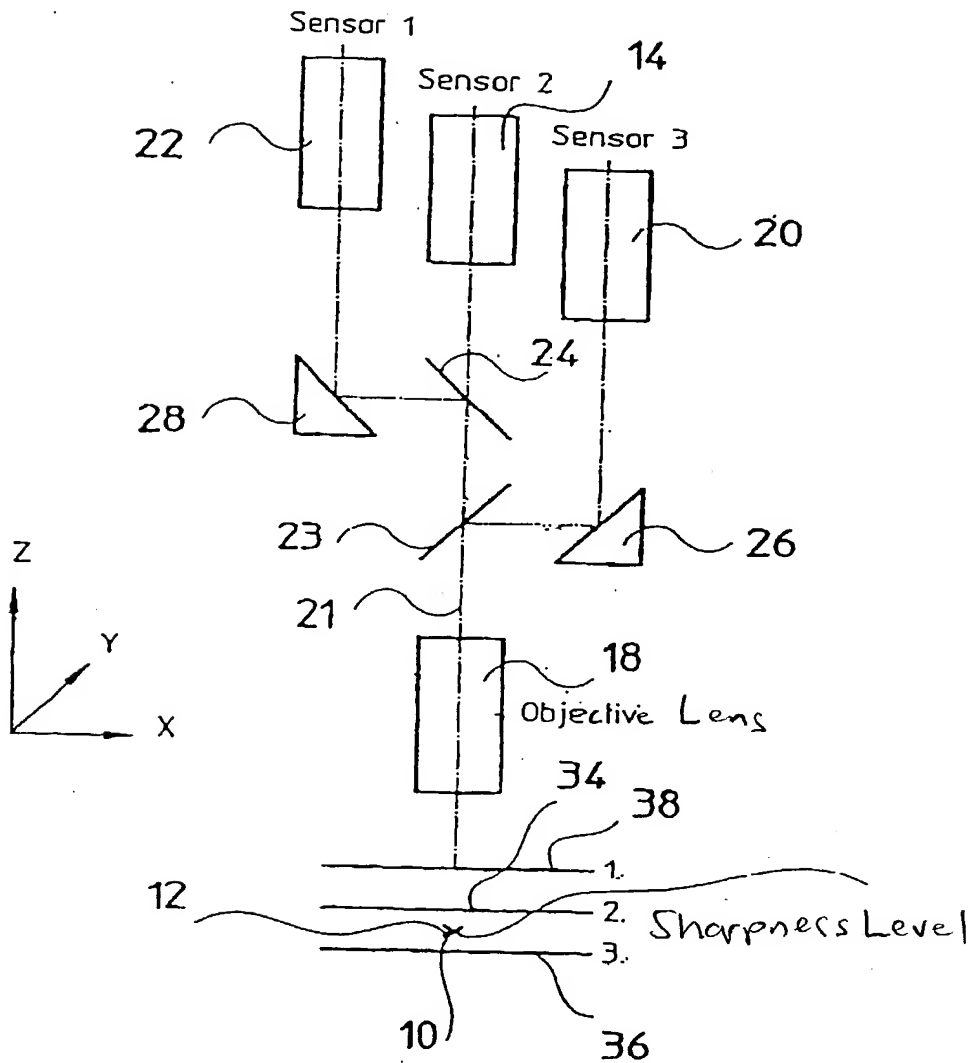


(57) Abstract: The invention relates to a method and a device for determining the distance from a point (10) on an object (12) to a sensor (14, 20, 22) by measuring the contrast values of the point that is represented in the working plane of the sensor. According to the invention, the contrast distributions of the beams are determined at the ends of at least three optical paths of different lengths in the imaging beam path of the optical system (18) according to the distance to the point of the object to be measured, using at least one sensor, and a relationship is established between the resulting contrast distributions. In this way, the distance between the object and the sensor can be determined quickly and accurately.

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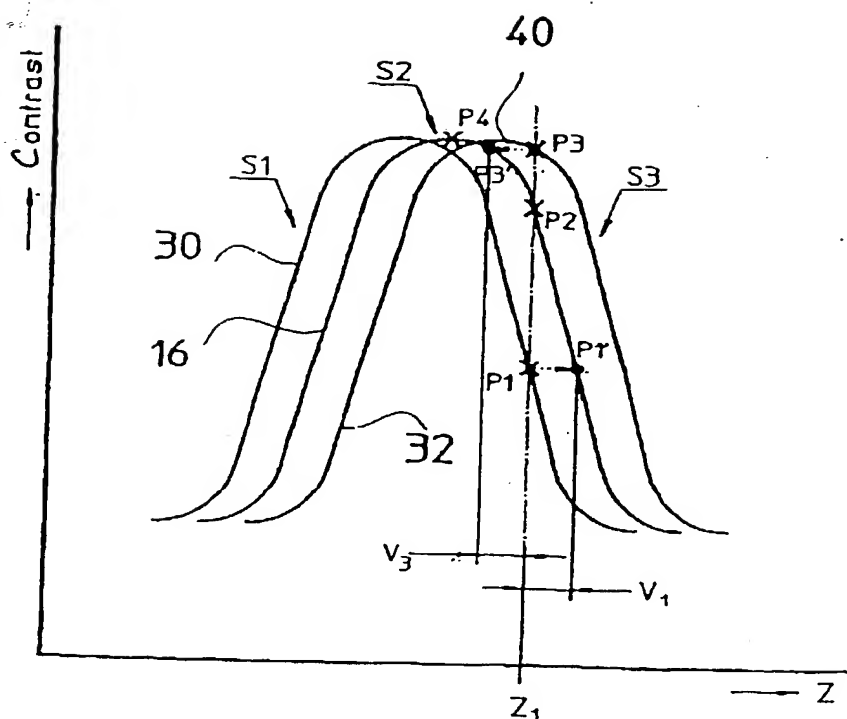
WO 01/33166 A1

Figure 1



(Drawing)

Figure 2



DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION

Docket No. _____

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

AUTOMATIC CONTRAST FOCUSING WITH THREE OPTICAL PATHS

_____, the specification of which
(check one) ☒ is described and claimed in PCT International Application PCT/EP 00/10842 filed on
(MM/DD/YYYY) _____ amended on _____ (if applicable) (OR) _____ is described in United States Application
Number _____ filed on (MM/DD/YYYY) _____ (OR) _____ is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Claimed? Yes No
199 52 833.0	DE	11/03/1999	<input checked="" type="checkbox"/> <input type="checkbox"/>
199 56 761.1	DE	11/25/1999	<input checked="" type="checkbox"/> <input type="checkbox"/>
			<input type="checkbox"/> <input type="checkbox"/>

I hereby claim the benefit under 35 U.S.C. 119(c) of any United States Provisional Application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)

I hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or 365(c) of any PCT International application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

U.S. Parent Application or PCT Parent	Parent Filing Date	Parent Patent Number

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. §1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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